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HUMAN CAPITAL MEASUREMENT: A SURVEY

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Abstract. After a short history of the concept of human capital (henceforth HC) in economic thought (Section 1), this study presents the two main methods for estimating the value of the stock of HC – the retrospective and prospective one – with a review of the models proposed (Section 2). These methods are linked both to the theory of HC investment as a rational choice (Section 3), the literature analysing the contribution of HC investment to economic growth and the HC estimating method through educational attainment (Section 4). The more recent literature on HC as a latent variable is also assessed (Section 5) and a new method of estimation where HC is seen both as an unknown function of formative indicators and as a 'latent effect' underlying earned income is proposed (Section 6). Section 7 concludes.

Keywords. Human capital history; Latent variable analysis; Returns to education

1. Introduction

The concept of human capital (henceforth HC) is an old one. Perhaps the first to try to define and measure what we now call HC was Sir William Petty (1623–1687) (Petty, 1690). The most prominent founder of the Political Arithmetic School of Economics and a forerunner of applied econometrics, Petty was concerned with the main national socioeconomic and political roles of HC. He believed that labour was the 'father of wealth' and that a measure of its value should be included in the estimation of national wealth. Petty's thesis was that factors other than land and population were important in determining the wealth of a nation. Besides interest in demonstrating the power of the nation, there were other reasons for estimating the stock of HC: for example, to measure the value of lives destroyed in war or the monetary loss due to deaths or associated with migration, or to offer a sound base for taxation.

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Petty's measurement of the value of the stock of HC was based on capitalizing the wage bill (the difference between national income and property income) to perpetuity using the interest rate as discount factor.

After Petty, Cantillon (1755) and Smith (1776; quotation from the 1976 edition) discussed the concept of HC. Cantillon was more interested in defining the costs of maintaining a slave and his offspring than in estimating the value created by HC (see Hofflander, 1966). Smith's purpose in discussing the concept was somewhat different from those of both Petty and Cantillon. Smith's principal aim was not to measure the 'value of the stock of human capital' but to understand the reasons why there are different remunerations between different occupations.

Smith envisaged five main circumstances which may give rise to differential pecuniary gains in employment: (i) the agreeableness or disagreeableness of different employments; (ii) the differing difficulty and expense of learning them; (iii) the differing job security in them; (iv) the differing amount of trustworthiness required for them and (v) the differing probability of success in them.

Smith included the acquired and useful abilities of all the inhabitants or members of the society under the idea of capital. He wrote 'the acquisition of such talents, by the maintenance of the acquirer during his education, study or apprenticeship, always costs a real expense, which is a capital fixed and realized, as it were, in his person [. . .]. The improved dexterity of a workman may be considered in the same light as a machine or instrument of trade which facilitates and abridges labour, and which, though it costs a certain expense, repays that expense with a profit' (pp. 265–266). 'The work which he learns to perform, it must be expected, over and above the usual wages of common labour, will replace to him the whole expense of his education, with at least the ordinary profits of an equally valuable capital. It must do this too in a reasonable time, regard being had to the very uncertain duration of human life, in the same manner as the more certain duration of the machine' (p. 101).

According to Smith, the sources of HC are experience, associated with the specialization of the economy (division of labour), and education in schools, colleges or apprenticeships. According to Smith, 'innate differences' make a minor contribution to individual embodiments of HC (Spengler, 1977), because 'differences [. . .] seems to arise not so much from nature, as from habit, custom and education' (pp. 28–29). Overall, it was Smith's belief that the growing system of capitalist factories would have the effect of devaluing HC measured as skills and abilities because the factory system required only homogeneous unskilled labour.

For a long time there was no consensus among authors on the question of whether the skills and abilities possessed by labourers could be identified as HC. Many were reluctant to use the term on ethical grounds because they did not want to treat human beings as machines. Smith, for instance, did not use the term, but compared skills and acquired abilities to 'an expensive machine', thereby distinguishing human life and the human being him/herself from the decision to undertake costly investment in order to become more productive, which can be likened to any other investment.

For almost two centuries the main purpose of estimating HC was to measure the stock of its value. This raised two questions. The first was whether it is 'moral' to

treat human beings (men and women) as a resource whose value can be measured in monetary terms. Is it possible to distinguish between human beings *per se* and their skills and abilities? What exactly is measured: the 'value' of human beings or the value of certain of their characteristics? This problem – that of the 'nature' of what is today called HC – will be discussed in this section. The answer to this question also has consequences, as we shall see, on the way in which the value of HC can be 'measured'.

Second, for a long time before the industrial revolution (and also in its first phases) labour was relatively homogeneous (being almost entirely rural or low skilled). Hence the problem of the 'quantity' of embodied HC (i.e. the level of health and productive 'strength' of labourers more than their knowledge) was linked to certain basic characteristics of individuals. As a consequence, the problem of measuring the value of the stock of HC was linked to measuring the value of these basic characteristics, and less to measuring the value of specific voluntary decisions to invest in HC. The problem could be addressed from a national accounts perspective in a relatively easy way.

Once it has been decided to measure the 'value' of the productive force of human beings, what methods can be used to make these estimations? Section 2 discusses the two main approaches to such measurement, the first based on estimation of the costs of producing HC, the second on the estimation of the present value of future (gross or net) earnings. Not discussed are the more recent approaches based on utility functions and the concept of willingness-to-pay used in cost–benefit analysis.

Section 3 analyses the more recent micro approach to modelling investment choices in HC and their rationale proposed by members of the Chicago School in the middle of the last century. Section 4 reviews the attempts that have been made to estimate the quantity of the stock of HC both at the macro and the individual level, the empirical literature based on the Mincer approach correlating individual HC and earnings, and the macro literature that studies the relation between the aggregate stock of HC and the capacity of a society to grow. Also discussed in Section 4 are the major problems involved in estimating both the quantity and the quality of HC. Sections 5 and 6 suggest a new approach to the measurement of HC considered as a latent variable (LV), and propose a new model for its estimation. Section 7 concludes.

As we have seen, Adam Smith did not use the term 'HC', but instead included the 'value' of acquired skills and abilities in the notion of capital. Mill (1848), in his *Principles of Political Economy* (quotations from the 1909 edition), stated that we cannot define human beings as capital: 'A country would hardly be said to be richer, except by metaphor, however precious a possession it might have in the genius, the virtues, or the accomplishments of its inhabitants; unless indeed these were looked upon as marketable articles, by which it could attract the material wealth of other countries' (p. 48) (and for this reason Mill is considered a dissenter in the theory of HC). But Mill goes further. Starting from the principle that we need a market in order to determine the value of a thing, he enquires whether there is a market for acquired abilities and skills. The answer is affirmative. Later in the

same book, Mill argues that because acquired abilities are costly and make men more productive, they must be treated as capital, thus taking up a position similar to that of Adam Smith: 'The human being himself I do not class as wealth. He is the purpose for which wealth exists. But his acquired capacities, which exist only as a means, and have been called into existence by labour, fall rightly, as it seems to me, within that designation' (p. 47). A comparable opinion was put forward by other authors. Friedrich List stated that acquired abilities are partly an inheritance of past labour and self-restraint and are the most important part of a nation's stock of capital.

Alfred Marshall (1890; quotations from the 1920 edition) adopted a position similar to Mill's in arguing that it is not possible to value human beings *per se*: 'Where a sale of the article is scarcely conceivable, an appraisement is almost out of the question. To estimate the value of the Yellowstone Park is impossible, unless we allow ourselves a range of several hundred per cent. Similar wide limits must be allowed when we try to value free human beings. We can often give a lower limit, but seldom an upper one [. . .]. It would be wrong, however, to conclude, as some writers have, that because we cannot value them accurately, public parks or freemen cannot be called wealth' (p. 17). Marshall's conception of HC is similar to Mill's: 'We may define personal wealth so as to include all those energies, faculties and habits which directly contribute to making people industrially efficient' (p. 58).

Other scholars suggested that the idea of HC (and estimation of its value) regarded the human being him/herself. J.R. McCulloch (1789–1864) wrote in his *Principles of Political Economy* (McCulloch, 1849): 'Instead of understanding by capital all that portion of the produce of industry extrinsic to man, which made be applicable to his support, and to the facilitating of production, there does not seem to be any good reason why man himself should not, and very many why he should be considered as part of the national capital' (1849, p. 121). According to Nassau Senior (1790–1864), it may be useful to treat human beings as capital: from an economic point of view there is little difference between talking of the value of a free man and of a slave (Senior, 1836, p. 133).

More recently, Dennison (1962, 1967) asked whether the value of an individual's useful abilities and skills and the value of that individual him/herself are the same thing. Given that the former are embodied in the human being, it is difficult to distinguish between the two. In the same years, Schultz, one of the founders of the Chicago School of HC analysis, noted that 'our values and beliefs inhibit us from looking upon human beings as capital goods, except in slavery, and this we abhor [but . . .] there is nothing in the concept of human wealth contrary to [the] idea that it exists only for the advantage of people. By investing in themselves, people can enlarge the range of choice available to them. It is one way free men can enhance their welfare' (Schultz, 1961, p. 2).

Schultz's argument was in line with the new approach taken to the rational choice of investing in HC. Instead of focusing on the state's aim of enhancing the wealth or power of the nation, the new approach sought to determine the reasons why an individual would decide to invest in his/her personal skills. The distinction between

the value of the person, which extended beyond the economic dimension, and the value of his/her skills was thus made clearer.

Section 2 briefly presents the two main methods used to measure the value of HC from an aggregate point of view in order to understand the contribution of this value to the overall wealth of a nation. Section 3 discusses the approach based on household or individual investment choices (the Chicago Human Capital School of Schultz and Becker) and the consequent literature that sought to measure (both as total stock and as differential stock between individuals with different characteristics) the 'quantity' of HC embodied in individuals, and to determine its sources.

2. Methods to Estimate the Value of the Stock of Human Capital

The retrospective method approaches the problem from the viewpoint of the cost of producing a human being, or better the cost of his/her rearing. The basic assumption is that the value of the HC embodied in a person is equal to the cost of producing that same 'wealth'.

Ernst Engel (1883) was the first scholar to use what was essentially the retrospective method. Engel considered three (lower, middle and upper) German social classes and applied a simple formula to estimate the cost $c_{0,i}$ ($i = 1, 2, 3$) at birth of each class. He estimated $c_{0,i}$ to be 100, 200 and 300 German marks for the lower, middle and upper German social classes respectively.

A second assumption was that this cost rises annually according to a simple arithmetic progression of ratio ρ relatively to the previous year. Engel estimated $\rho = 0.10$. Third, he suggested that a man is 'fully formed' at the age of 26 and that a woman is fully formed at the age of 20, so that their cost of maintenance ceases. Hence, at age a, the monetary value of a human being belonging to the ith social class, $C_{a,i}$, is

$$C_{a,i} = c_{0,i}\left[1 + a + \rho\frac{a(a+1)}{2}\right] \qquad i = 1, 2, 3 \qquad (1)$$

$$a \leq 26 \text{ for men}, a \leq 20 \text{ for women}$$

Given the simplicity of Engel's assumptions, this approach should not be taken as estimating either an individual's HC or the 'monetary value' of a human being. It is only a historical and very simplified way to estimate rearing costs which does not include interest on past investments (capitalization) and is performed using a strictly actuarial approach which omits social costs such as education, health care, sanitation and the social cost of those who do not survive (for the importance of health in defining HC, see Lye and Hirschberg, 2010).

The costs of production and rearing approach was taken up by several other scholars working in the Italian economics tradition, like Pareto (1905), Beneduce (1904), Sensini (1908), Pietra (1931), Gini (1931) and Ferrari (1932).

Engel's simple assumptions concerning the basic cost of rearing a child and the growth of this cost over time gave rise to various problems that various economists

and statisticians sought to solve. Giorgio Mortara (1934) used the concept of adult-equivalent units of consumption. The value of the consumption for a person of age a at year T, for example, is equal to the sum of the cost of rearing a person of age 1 plus the yearly cost of rearing a person of age 2, and so on to age a, using the consumption values of the different cohorts in year T and also considering the probability of survival by using appropriate mortality tables.

Dublin and Lotka (1930) proposed a sophisticated version of Engel's approach. The cost of production (rearing) an individual to age a, C_a, was, according to Dublin and Lotka,

$$C_a = (\pi_a)^{-1}\left[\sum_{t=0}^{a-1}(1+i)^{a-t}\pi_t(c_t - y_t E_t)\right] \tag{2}$$

where π_t is the probability of survival at age t, i is the interest rate, c_t is the per capita cost of living from age t to age $t+1$, y_t are the earnings of the individual from age t to age $t+1$ and E_t is the proportion of individuals employed from age t to age $t+1$.

Friedrik Kapp (1870) utilized Engel's cost-of-production procedure (neglecting depreciation and maintenance) to estimate the value of an immigrant arriving in the USA (see Kiker, 1966, p. 493). This approach to the value of immigration was criticized by Mayo-Smith (1890) on the ground that the capital value of an immigrant is not only defined by the cost of production but also by demand: it depends on the monetary value for the country in which he/she enters.

More recently, Kendrick (1976) and Eisner (1985) have defined the value of the stock of HC using a cost-based approach. Kendrick divides spending on HC between tangible and intangible investments. The former, as in Engel, refer to the cost of 'producing' and rearing an individual until the age of 14. Intangible investments refer to the cost of enhancing the quality (or productivity) of labour and are inclusive of expenditures on health, safety, mobility, education and training, plus the opportunity cost of attending school. This is an approach to estimating the flow of resources invested in education that may prove very useful for cost–benefit analyses. Moreover, it is extremely difficult to measure the cost of individual and family investment in HC. The total costs of education, housing, food, clothing, health care and transportation are indistinguishable from the costs of investment in HC. Hence these costs are not rigorously taken into account when household HC investment is estimated (Dagum and Slottje, 2000).

Many criticisms have been made of the cost-based approach. The most important of them is that there is no relation between the cost of production (investment) and the quality of output. This problem is a very serious one when treating HC. All costly investments in abilities and skills are made over an un-produced innate base which differs and may be very important in determining the value from the demand side of HC.

Second, not all the components involved in the production of acquired skills and abilities are well identified. Must the total cost of rearing be considered, as

Kendrick (1976) assumes, or the total cost approach is right only if we consider people as slaves (Bowman, 1969)?

A third criticism is that this approach disregards both social costs associated to non-market activities (such as public investments in education and health) and their value in generating HC (family education, cultural context, opportunities for self-fulfilment and a good environment are all elements important in the formation of individual capabilities: Haveman and Wolfe, 1984; Dagum and Vittadini, 1996). For a good review of criticisms against the cost-of-production approach, see Jorgenson and Fraumeni (1989) and Le *et al.* (2003). There follows a synthetic assessment by Kiker (1966): 'The [cost of production] method is the less useful, since there is no simple and necessary relationship between the cost of producing an item and its economic value. The inseparability of consumption and investment and the difficulty of treating depreciation and maintenance make any cost-of-production value dubious' (Kiker, 1966, p. 497).

As noted above, Petty estimated England's national income and deducted property income from it to obtain the value of the wage bill or earned income. He considered the latter to be a flow of annual income to perpetuity: hence his estimate of England's HC in a given year was its wage bill divided by the market rate of interest. Besides his interest in public finance, and therefore in taxation, Petty's analysis of HC was also motivated by his concern to demonstrate the economic power of England, the economic effects of migration, and the cost of human lives lost in war.

A rigorous scientific approach to estimating an individual's HC through the application of actuarial mathematics was developed by Farr (1853), who estimated an individual's HC as the present actuarial value of the expected annual earnings (weighted by the survival probability) net of maintenance costs (personal living expenses). Farr's aim was to find an appropriate measure of the capacity of each individual to contribute to national taxation. He considered that the value of a person's property was a good base for such a capacity and that HC constituted a very large part of this property. Farr assumed that 'the present value of the person's probable future earnings, minus the necessary outgo in realizing these earnings is the present value of that person's services' (Farr, 1853, p. 38 – see Hofflander, 1966). In defining both earnings and cost of maintenance, Farr used tables of mortality/survival in a finite time horizon in which individuals can gain earnings and make profits over their costs. These are the two main differences with respect to Petty's method.

A method similar to Farr's was proposed by Alfred Marshall, who treated an individual's income and maintenance costs as continuous rather than discrete variables, and it was perfected 80 years later by Dublin and Lotka (1930).

Some years after Farr's contribution, T. Wittstein (1867) combined Farr's prospective and Engel's retrospective approaches to estimate a person's HC as the basis for assessing compensation for loss of life. The weakness of Wittstein's approach was its unacceptable assumption that lifetime earnings are equal to lifetime maintenance.

Giffen (1880) used an approach essentially similar to Petty's method to estimate the total costs of the combatants lost in the Franco-German war.

Dublin and Lotka (1930) worked in the insurance sector and proposed a method of estimating a person's money value at various ages in order to provide guidelines for insurance contracts. They sought to give more precise and formal definition to Farr's method by allowing for unemployment, rather than assuming full employment (as Farr did).

Their revised formula for estimating an individual's value at birth, V_0, was the following:

$$V_0 = \sum_{x=0}^{\infty} \frac{p_{0,x}(y_x E_x - c_x)}{(1+i)^x} \tag{3}$$

where i is the interest rate, $p_{0,x}$ the probability at birth of an individual surviving to age x, y_x the annual earnings per individual from age x to $x+1$, E_x the annual employment rate at age x, and c_x an individual's cost of living from age x to age $x+1$.

From the above formula we can obtain the money value at each particular age, a:

$$V_a = \sum_{x=a}^{\infty} \frac{p_{a,x}(y_x E_x - c_x)}{(1+i)^{x-a}} \tag{4}$$

and the cost of rearing a person up to age a:

$$C_a = \sum_{x=0}^{a-1} \frac{p_{a,x}(c_x - y_x E_x)}{(1+i)^{x-a}} \tag{5}$$

Expanding (5) and substituting yields the two different equations

$$V_a = \frac{(1+i)^a}{p_{0,a}} V_0 + C_a \quad \text{and} \quad C_a = V_a - \frac{(1+i)^a}{p_{0,a}} V_0 \tag{6}$$

which simply state that the cost of producing an individual up to age a is equal to the difference between his/her value at age a and the present value, at age a, of his/her value at birth adjusted for survival probabilities.

Farr's approach was widely used – with some changes and refinements – by many scholars. Examples are the studies by De Foville (1905) and Barriol (1910) who sought to calculate the social value of French male workers by dividing their population in different age groups. As regards the USA, Fisher (1908) adopted Farr's approach to assess the costs of preventable diseases, and Huebner (1914) used a similar approach. Woods and Metzger (1927) employed five different methods. Wickens (1924) applied the capitalization of earnings method to estimate the stock of wealth in Australia. According to Kiker (1966), these studies were not free from erroneous assumptions.

Weisbrod (1961) employed a modified version of Dublin and Lotka's formula, the main difference being that the analysis was made, not with macro, but with sectional data for earnings, employment rates and survival probabilities (Le *et al.*,

2003):

$$V_a = \sum_{x=a}^{\infty} \frac{Y_x W_x p_{a,x}}{(1+i)^{x-a}} \tag{7}$$

where V_a is the present value of expected future earnings of an individual of age a, Y_x is the average expected earnings for that individual at age $a+x$ (expectations are based on observed earnings of other individuals with the same characteristics and aged x years older), W_x is the employment rate at the same age, $p_{a,x}$ is the probability of survival at age x of a person of age a, and i is the discount rate.

Because in a growing economy expected earnings can increase with seniority and other factors associated with age, Graham and Webb (1979) adjusted the Weisbrod approach to incorporate the effects of both growth and individual characteristics (among them education). They acknowledged that the value of HC has both market and non-market dimensions, noting for example that 'one of the primary benefits of schooling is certainly the greater efficiency and adaptability displayed by the more educated in performing a myriad of non-market chores such as child rearing, personal finance and homemaking, health investments, search activities and even additional HC investments' (p. 212). However, they were aware that non-market dimensions are very difficult to measure, and also realized that the share of returns on HC incorporated not in personal earnings but in employer's profits is indistinguishable from the contribution of factors other than HC. They maintained that property income, interest, dividends and transfer payment can hardly be considered part of the value of HC. Instead, it is more correct to use data on earnings (to measure the market value of HC) rather than income data. At the time when Graham and Webb conducted their analysis, sufficient information on earnings was available from surveys.

They proposed the following formula to take account of both individuals' characteristics and the growth path of the system in which they live:

$$PV_x^i = \sum_{x=a}^{N} \frac{E_x^i W_x^i p_{a,x}^i \prod_{k=a}^{x} \left(1+x_k^i\right)}{\prod_{k=a}^{x} \left(1+r_k^i\right)} \tag{8}$$

where PV_x^i is the present value of future earnings (until age N, the feasible upper bound of life) of an individual of age x with a vector of characteristics i and g_k^i and r_k^i are the expected growth rate of earning and the interest rate on earnings that an individual with characteristics i considers consistent for earnings made in year k. E_x^i are the expected earnings of an individual with i characteristics at year x, and $W^i{}_x$ and $p_{a,x}^i$ are the probabilities of being employed at age x and of being alive at the same age, respectively.

Jorgenson and Fraumeni (1989, 1992) extended and improved this method by classifying population according to some fundamental characteristics, sex, age and educational groups (for a total of 2196 cohorts: see Le *et al.*, 2003, p. 283). In this manner they produced an estimation of HC for the entire US population. They measured the value of HC – the lifetime income (earnings) – of an individual by means of a recursive method. More specifically, the lifetime income of an individual

at age a was equal to his/her earnings in the current year plus the lifetime income of that individual at age $a + 1$ weighted by the probability of surviving, the growth in individual educational attainment, and the growth of earnings linked to the evolution of the economy. Jorgenson and Fraumeni assumed that individuals retire at 75, so that the life income of a person aged 74 exactly coincided with his/her current yearly earnings. A lifetime income for a person aged 73 was his/her yearly current earnings plus the discounted value of his/her lifetime income at 74 (weighted by the probability of surviving).

More specifically, calling $life_{y,s,a,e}$ the lifetime income at year y, for a person of sex s, age a and educational level e, we have

$$life_{y,s,a,e} = yi_{y,s,a,e} + \{senr_{y,s,a,e} sr_{y,s,a,a+1} life_{y,s,a+1,e+1} + (1 - senr_{y,s,a,e}) sr_{y,s,a,a+1} life_{y,s,a+1,e}\} \frac{1+g}{1+i} \quad (9)$$

where $yi_{y,s,a,e}$ is the current year income for that individual (which for Jorgenson and Fraumeni includes both market and non-market elements); $senr_{y,s,a,e}$ is the school enrolment rate for the group of similar individuals, and $sr_{y,s,a,a+1}$ is the probability of that individual surviving at age $a + 1$. The letters g and i denote the rate of growth of the economy and the discount rate respectively.

As reported by Le *et al.* (2003): 'While cost-based studies found the HC stock to be about the same size of the physical capital stock and earlier income-based studies typically observed the HC stock to be from three to five times greater than the physical capital stock, Jorgenson and Fraumeni (1989) showed that HC was from 12 to 16 times more than physical capital in size' (p. 284).

Jorgenson and Fraumeni's method has been widely used, but it has been criticized because it overestimates non-market activities. The hypothesis of the model is that HC raises the productivity of time spent on leisure exactly as it raises the productivity of time spent on work (for a criticism see Dagum and Slottje, 2000; Le *et al.*, 2003, 2006). Moreover according to Jorgenson and Fraumeni's hypotheses, unemployment also affects the distribution of HC between market and non-market activities, but it does not change the level of the value of HC (Conrad, 1992; Rothschild, 1992). To avoid this criticism, Le *et al.* (2006) in a study on New Zealand exclude the HC of individuals who are out of employment as well as the contribution that employed individuals make outside paid work. Also a recent study by Wei (2008) on Australia applies the Jorgenson–Fraumeni method without considering non-market activities. For a good review of studies that change some controversial Jorgenson–Fraumeni hypotheses see Oxley *et al.* (2008).

In conclusion in the income-based approach to measure the effects of HC investment, the rate of return of earned income must be calculated so the lifelong household income based on personal income, actualized by means of an adequate actuarial method, can be considered as a proxy of the effects of investment in HC and utilized as a reflective indicator. Various earnings categories (i.e. higher post-tax earnings, extra tax earnings, capital income derived by investment in HC) can be used as reflective indicators (OECD, 1998).

The income-based methods measure the value of HC at market prices, and market prices account, at least to a certain extent, for many factors, such as ability, effort, professional qualifications and also the quality of the institutional and technical context in which activities are undertaken (Dagum and Slottje, 2000). Second, this method does not need to estimate an arbitrary depreciation rate of HC since this is still embodied in the inter-temporal flows of earnings. Third, because this method is forward looking and enables account to be taken of growth dynamics, it seems better suited to societies that are growing and want to be informed about their future productive capacities. Therefore, the method – as assessed in Le *et al*. (2003) – is more reliable than the retrospective method if, as happens today, there is a much greater availability of good data compared with the past. The literature regarding HC testifies that there are abundant sources available for measuring the return of the investment in HC (i.e. aggregate rate of employment, number of highly skilled workers, labour market training programmes, technical know-how and innovation). Life tables are now available, and so are surveys on earnings and (un)employment rates by age and educational level (United Nations, 2002). The choice of a discount rate involves some subjective judgment, but most importantly a forward-looking dynamic economy is interested in evaluating its future productive capacities, not in estimating the 'stock of the wealth from historical values' (Graham and Webb, 1979). See, for example, Millimet *et al.* (2010) for new and more accurate methods to build worklife expectancy tables.

However, the income-based approach also has some drawbacks. It crucially relies on the hypothesis that differences in wages truly reflect differences in productivity. Wages vary for numerous reasons: trade unions may bias the relation between the two phenomena, and real wages may fall in economic downturns (but not real productivity). Income-based measures of HC are quite sensitive to the discount rate and the retirement age so that analysts should be cautious when using the results. Moreover it should be kept in mind that the value of HC (like the value of physical capital) depends not only on the cost of production but also on its demand as well as non-market activities (Jorgenson and Fraumeni, 1989; Le *et al.*, 2003). Finally, data on earnings are not as widely available as data on investments, especially in the case of developing countries where the wage rate is often not observable.

A second issue concerns the debate on maintenance costs. In order to maintain the analogy with physical capital estimations (which are figures net of maintenance costs), these expenditures should be deducted. De Foville (1905) and Eisner (1985), for example, criticized the income-based method for not deducting maintenance costs from gross earnings.

Weisbrod's attempt to account for maintenance expenses encountered many difficulties (Weisbrod, 1961). What types of expenditure must be classified as maintenance? How can account be taken of economies of scale when estimating per capita consumption in the same household? These problems cannot be easily solved. Other authors (e.g. Graham and Webb, 1979; Jorgenson and Fraumeni, 1989) maintain that consumption is an end, rather than a means, so that gross earnings constitute a more relevant variable to use when estimating HC using a lifetime labour income approach, whereas net productivity is the more relevant

measure if the aim is to estimate the value of a person to others, not to society. Macroeconomic considerations aside, it is extremely difficult to measure the cost of individual and family investment in HC. In fact, Dagum and Slottje (2000) have stated that the total costs of education, housing, food, clothing, health care and transportation are indistinguishable from the costs of investment in HC.

Third, average benefits to individuals and employment prospects are often clear, but it is not always easy to quantify the benefits to society and above all to individuals and households (OECD, 1998). Finally, there is a lack of general surveys on individuals regarding these characteristics (OECD, 1998).

3. Investment in Human Capital as a Rational Choice

A major shift in the approach to the question of HC occurred in the second half of the twentieth century with the advent of a micro-founded model of rational choice in HC investment linked with the names of Schultz (1959, 1961), Becker (1962, 1964) and Mincer (1958, 1974) at the University of Chicago.

The fundamental idea behind the approach is that the individual 'quantity' of HC is the result of voluntary investment in acquiring skills and abilities by the individual or his/her family. The decision to invest is similar to that regarding investment in physical capital (Schultz, 1961), the difference being that education and training effects are embodied in a person's characteristics (and can neither be alienated nor bought as a capital good). It is therefore necessary to define HC with a new and specific concept. Becker (1962) discussed the different forms that investment in HC may take: on-the-job learning (apprenticeship, internship, on-the-job training, etc.) and schooling are by far the two main methods used to upgrade HC.

Becker modelled a decision process of investment in training and education to account for the observed growth of earnings with age, at a decreasing rate, and more generally to explain why, if it is reasonable to assume that innate abilities are normally distributed, earnings have a much more skewed distribution. His hypothesis was that this depends on investment in HC.

Investments can be made both by individuals (or their families) and by firms. Firms can sustain the costs of training and on-the-job learning if and only if they can reasonably presume that the trainee will remain with the organization (i.e. if the training is sufficiently specific); otherwise the costs of training (and education) will be sustained by the person or his/her family. Consequently, the distinction between general and specific training and education is of great importance in Becker's analysis.

The acquisition of knowledge through the school system can be regarded as general training; conversely, the majority of on-the-job learning is at least partially specific. Moreover, the effects of higher education are apparent in the earnings differentials of individuals (other things being equal), and the value effects of on-the-job training appear partly in earnings increases of an individual and partly in the firm's economic results; the latter are non-separable from the effects of numerous other dimensions of the firm's activity. It is for this reason that, in empirical studies,

researchers have tried to measure the returns to schooling and aggregated all other effects in a generic variable 'experience'.

By modelling the problem of the value of HC as a rational investment decision, Schultz and Becker offered a possible solution to the ethical issue of what should be measured: the 'value' of human beings, or only the value of their abilities. It was now made clearer that we are measuring the latter dimension. Perhaps the main shortcoming of the Chicago School was that it never tried to measure the value of the aggregate stock of HC and its distribution within a population.

Mincer's work is the cornerstone of the literature on the relationship between earnings and HC investments at the individual (or household) level. Its theoretical background is similar to Becker's (1964) and focuses on the relationship between completed schooling and average earnings over the lifecycle. It may be viewed as a specification of the more general approach using hedonic wage functions that connects wages, investment in education and ability (Rosen, 1974, 1977).

The classical Mincer approach links the logarithm of average earnings to completed years of schooling and years of experience:

$$\ln \boldsymbol{w}(s, x) = \alpha_0 + \rho_s \boldsymbol{s} + \beta_0 \boldsymbol{x} + \beta_1 \boldsymbol{x}^2 + \varepsilon \tag{10}$$

where $\boldsymbol{s}$ denotes years of schooling, $\boldsymbol{x}$ is experience and $\boldsymbol{w}(s, x)$ are the earnings of an individual with s schooling years and x experience years.

Equation (10) can be derived from two different models proposed by Mincer in 1958 and 1974 respectively. The theoretical foundations of the two models are different (we follow Card, 1999; Heckman *et al.*, 2003).

1. *The Compensating Differences Model (Mincer, 1958)*
   In his first model, Mincer assumed that individuals have identical abilities and opportunities, there are perfect credit markets, the environment is perfectly certain, and occupations differ in the amount of training required for them. Schooling is costly because of earnings forgone while at school. Since individuals are identical, they need a compensating differential to work in occupations that require longer training periods. The size of this compensating difference is determined by equating the present value of the earning streams (net of costs) associated with different levels of investment.
2. *The Accounting-identity Model (Mincer, 1974)*
   This model builds on an accounting-identity framework along the lines of Becker (1964) and Becker and Chiswick (1966). The assumptions are totally different from those of the former model: potential earnings in any time period depend on investments made in previous periods. Investments in training are a fraction of potential earnings, $C_t = k_t E_t$, where k_t is the fraction of potential earnings (E_t) invested at time t. Then:

$$E_{t+1} = E_t + C_t \rho_t = E_t(1 + k_t \rho_t) \tag{11}$$

   where ρ_t is the return on training investment made at time t. Formal schooling implies full-time investment ($k_t = 1$). If we assume that the rate of return

on formal schooling is constant ($\rho_t = \rho_s$), that the rate of return on post-school investment is also constant (ρ_0) and that post-school investment shows a declining rate, for small ρ_s and ρ_0 we can approximate (11) with

$$\ln \boldsymbol{w}(x, s) = \alpha_0 + \rho_s \boldsymbol{s} + \beta_0 \boldsymbol{x} + \beta_1 \boldsymbol{x}^2 + \varepsilon \tag{12}$$

i.e. the model in equation (10).

There are some empirically testable implications of the accounting-identity model which derive from its assumptions about the relationship between formal schooling and post-school investments: first, separability between schooling and experience implies that for any individual $w(s, x) = \mu(s)\varphi(x)$, and as a consequence the trend of earnings per experience level should be parallel for different schooling levels; second, linearity of log earnings in schooling implies that there are no decreasing returns in education (for a criticism on this assumption see Psacharopoulos, 1994; Wössmann, 2003).

Various authors have highlighted a number of problems with the Mincerian approach. For many years these criticisms were moderated by the fact that the log-linear specification appeared to fit the data very well (Card, 1999; Krueger and Lindahl, 2001), but recent studies have raised strong objections. Heckman *et al.* (2003), for example, extend the analysis of Mincer (1974) to both white and black males for the 1940–1990 period using US census data. They find that data for 1940–1950 censuses provide support for both separability and linearity. The evidence is weaker for 1960 and 1970 data, whereas data from 1980 and 1990 do not support the model at all.

Another criticism against the linearity of log earnings in years of schooling concerns the existence of diploma effects and their role of signalling ability and skills in the labour market (Arrow, 1973; Card, 2001).

A third and more radical criticism regards the assumptions of certainty and the idea that education choices are made in a static context, i.e. are based on the experience of older people. If we introduce uncertainty and a changing context where the information set changes over time, the internal rate of return is no longer an appropriate instrument for the evaluation of investment programmes. The Mincerian regression coefficient loses its information content and may have no meaning (Heckman *et al.*, 2003). Finally, another important drawback to the Mincer equation is that it does not control for individuals' ability (Cawley *et al.*, 2000).

In empirical studies, there is general agreement that returns to education are positive and high at individual level. Harmon *et al.* (2003) find a wide cross-country variation of returns but conclude that 'evidence on private returns to the individual is therefore compelling' (p. 150). In a recent paper, after surveying this large body of literature, Psacharopoulos and Patrinos (2004) report an average rate of return of 10% and a higher rate for low and middle income countries. The rates are different for males and females: women's rates of return are lower for primary school but higher for secondary and tertiary educational levels. Differential earnings for more educated workers depend on the context in which those workers operate. If the workers in an area (an urban one for example) have high HC (education) on average,

productivity feedbacks may augment the productivity of an individual worker. Sianesi and Van Reenen (2003) have sought to identify educational externalities by controlling for the average level of educational attainment in the town or in the region. Their equation is:

$$\ln w_{ijt} = \alpha_0 + \delta_j + \delta_t + \boldsymbol{x}_i'\boldsymbol{\mu} + \rho_s s_{it} + \gamma S_{jt} + u_{jt} + \varepsilon_i \tag{13}$$

where i refers to each individual, j to the region (or town), t to time, s_{jt} is the average schooling attainment of individual i at time t, and S_{jt} is the average schooling attainment in area j at time t; δ_j is a dummy for fixed effects linked to the area, δ_t is a dummy for time effects and $\boldsymbol{x}_i$ is a vector of individual characteristics.

Sianesi and Van Reenen have been criticized because of the endogeneity between s_{it} and S_{jt} and for not considering other effects (more nation-wide effects or more localized firm effects), or the effects of non-pecuniary externalities (quality of jobs, health, lower criminality etc.).

Rauch (1993) reports positive results for the presence of externalities. Acemoglu and Angrist (1999) find that coefficients of the variable measuring changes in the average stock of education in the area considered in the period 1960–1980 are positive but non-significant. The same model yields positive and significant results with more recent data (Acemoglu and Angrist, 2001). Ciccone and Peri (2006) find, with US data, that such externalities are non-significant. As said, private and social returns may also differ because private returns do not account for a large part of the cost of education, which is financed with public resources (Wössmann, 2003).

Another recent field of research regards the effects of mobility on wages, which are not considered in the standard Mincer model. Those effects, linked to transferable skills from one job to another, seem relevant (see Tchernis, 2010).

4. Human Capital and Economic Growth

The new approach to HC as a voluntary investment choice has introduced new ways to measure HC. The majority of studies that have followed this approach obtain the value of HC through a two-step procedure. The first step is estimating the stock of HC (its quantity) at either an individual or an aggregate level. The second is estimating the returns linked to the different level of HC as a proxy for its value or, alternatively, as a measure of the causal relation between HC and productivity growth.

A recent publication – OECD (1998) – terms this new approach based on the estimation of the quantity of HC (with stock or flows indicators) the 'educational attainment approach'.

The educational attainment approach measures the quantity of HC through attainment level indicators such as the percentage of the relevant population that have attained each level of education (from primary to tertiary levels), how many people have completed each level of education (in schools and universities), according to an international standardized base (at present the standardized reference is the International Standard Classification of Education – ISCED – proposed

by UNESCO in 1997, even if, according to the study of OECD (1998), ISCED is weak in many important aspects), the number of person-school years embodied in the labour force, the educational infrastructures, the ratio of government spending on education to GDP, the educational expenditure per student, and the student–teacher ratio (Barro and Lee, 1996; Hanushek, 1996; OECD, 1998; Wössmann, 2003). The educational attainment approach also suggests that region of residence, age, race and gender can alter the effects of equal amounts of investment in HC (Jorgenson, 1995; OECD, 1998; Wössmann, 2003).

The educational attainment method as a measure of the 'quantity' of HC has many drawbacks. First, educational attainment indicators give information on the initial, pre-job investment in HC. They ignore 'learning on courses that do not lead to a recognized qualification or less formal adult education as well as enterprise-based training' (OECD, 1998, p. 21). Antonelli *et al.* (2010) point out the importance of on-the-job training, particularly in innovative contexts. Moreover the stock of household HC is influenced by age of entrance into the labour market, job status, occupation, sector of activity, years of full-time and part-time work, depreciation of skills during the working life (especially if they are not used) (Jorgenson, 1995; OECD, 1998; Wössmann, 2003).

Second, indicators of the number of schooling years (for an individual) or the average of schooling years (for a population) have other serious drawbacks. In fact not only the quantity but also the quality of years of schooling influences the cognitive skills learned during each one of these years (Wössmann, 2003). In this direction, the quality ranking of schools and universities attended is strongly connected with quality of an educational institution and can also be utilized as a proxy of HC. Also factors such as personal intelligence and ability and family background may strongly influence the stock of HC (OECD, 1998; Le *et al.*, 2003, 2006; Wössmann, 2003). Moreover region of residence, age, race and gender can alter the effects of equal amounts of investment in HC (Jorgenson, 1995; OECD, 1998; Wössmann, 2003).

Third, measuring the stock of HC in schooling years implicitly gives the same weight to any year of schooling regardless of its level. But this forgets that numerous studies have found the existence of decreasing returns to years of schooling.

A last and more general criticism (which will be discussed further below) is that the quality of educational systems both within a country and among countries differs greatly. The number of schooling years required to attain a certain level differs among countries. In the OECD countries, for example, it is the tertiary level of education that has the greatest impact, whereas in developing countries it is primary schooling that counts most (Sianesi and Van Reenen, 2003). One solution would be to build another indicator that measures the average number of schooling years in the population, or subgroups of it, to correct for the variance in the duration of educational level across countries.

In sum, can educational attainment (levels, years) be considered a relatively good proxy for HC? The question was posed by Becker in his Nobel Lecture in 1992 (Becker, 1992); Cohen and Soto (2007) answered that it cannot. Indicators based on educational attainment have nevertheless been used by many scholars.

In growth accounting exercises, for example, Dennison (1967) treats education as one of the characteristics that generate changes in the productivity of labour (and hence, differences in earnings, under the assumption that the latter are equal to the marginal productivity of labour). Jorgenson (1995) uses an education-augmented definition of labour input. Azariadis and Drazen (1990) and Romer (1990) employ the adult literacy rate as a proxy for HC. Barro (1991), Mankiw *et al.* (1992) and Levine and Renelt (1991) use school enrolment ratios ($e_g = E_g/P_g$, where e_g is the enrolment ratio in grade level g, E_g is the number of students enrolled and P_g is the total population of the age group that, according the schooling system of the country, should be enrolled in grade g) as 'imperfect proxies of the flow of HC investment' (Wössmann, 2003). The method of gross enrolment ratios fails to account for the fact that the growth of the stock of HC is defined by the difference between the HC embodied in new entrants to the labour force and that embodied in those who retire.

An alternative to using educational attainment indicators (schooling levels completed, schooling years) is to assess skills directly. Experiments on surveys seeking to measure the skills of workers directly (in terms of literacy, numeracy and problem solving capacities) began in the 1990s (IALS surveys) for a pilot group of 12 countries. At present, survey data based on this approach (the Adult Literacy and Lifeskills – ALL – Surveys) are available only for a group of developed countries (see OECD, 1998; NCES, 2005).

Schooling years can also be used to estimate the costs of investment in HC, but only as a very rough proxy. It is extremely difficult to measure the real cost of individual and family investment in HC. In fact the total costs of education, housing, food, clothing, health care and transportation are indistinguishable from the costs of investment in HC. Moreover, private (household) expenditure on education is only a part of the real cost, because in several cases the greater part of the latter is sustained by public resources. Other possible indicators of investment in HC used in empirical research (at a macro level) are, for example, the ratio of government spending on education to GDP or educational expenditure per student (Barro and Lee, 1996; Hanushek, 1996; OECD, 1998; Wössmann, 2003).

A further use of educational attainment indicators is linked to the estimation of returns to education in order to measure the 'value' of HC as the discounted net present value of them – as in the prospective method. Mincer-type models have been utilized with aggregated data to measure the average impact of education on per capita GDP and hence, indirectly, the differential stream of income generated by HC. Under certain assumptions, the net present value of the stream of differential income due to education may represent an estimate of the value of the stock of HC.

To measure the effects of HC investment, the rate of return of earned income must be calculated, so the lifelong household income based on personal income, actualized by means of an adequate actuarial method, can be considered as a proxy of the effects of investment in HC and utilized as a reflective indicator. Various earnings categories (i.e. higher post-tax earnings, extra tax earnings, capital income derived by investment in HC) can be used as reflective indicators (OECD, 1998).

Survival probability and rate of productivity must also be taken into account in order to actualize the earning income (United Nations, 2002).

Empirical studies show discordant results. van Leeuwen and Földvári (2008), for example, find that the stock of HC in East European countries estimated through quantitative educational indicators is about 80% of that of the USA, while a measure based on prospective methods lowers this ratio to 20%.

According to OECD (1998), there is an alternative: instead of estimating the total value of the HC, it is possible to consider 'the ratio of the earnings of higher-educated to lower-educated workers [. . .] a measure of the former's human capital. By weighting different segments of the workforce by the ratio of earnings at different levels of education, it is possible to derive an index of the value of average human capital stock' (p. 28). An index-based approach to the estimation of the levels of HC was in the same years proposed by Mulligan and Sala-i-Martin (1997) and developed by Jeong (2002).

As stressed by Le *et al.* (2003), the main reason to 'measure' the stock of HC is to test the correlation between it and the capacity to grow of a society.

The results reported in this literature are contrasting. A first generation of studies found that HC has a major impact on growth and can explain the bulk of what is called 'Solow's residual' in growth accounting (Schultz, 1961; Dennison, 1962, 1967). As stated, some of these empirical analyses used indexes of adult literacy or enrolment rates (Azariadis and Drazen, 1990; Romer, 1990; Barro, 1991; Mankiw *et al.*, 1992; Levine and Renelt, 1992). Later analyses have tried to estimate the 'stock' of HC using the perpetual inventory method or similar approaches (Lau *et al.*, 1991; Nehru *et al.*, 1995; for a review see Wössmann, 2003). A second wave of studies has been more critical. Lau *et al.* (1991), using a model based on a Cobb–Douglas production function applied to 58 countries, found that education has negative effects in several non-developed regions and positive ones only in East Asia. Jovanovic *et al.* (1992) obtained similar results for a sample of developing countries.

The World Bank's 1995 *World Development Report* found that the importance of education in explaining aggregate growth was weak. Pritchett and Filmer (1999) showed that there is no positive relation between the growth of HC and productivity growth. Bils and Klenow (2000) found a positive relation between initial enrolment rates and productivity growth, but the coefficient associated with the stock of HC was negative. In their recent survey Sianesi and Van Reenen (2003) recognize the importance of the theoretical distinction between models that put HC in relation with the level of growth (in the neo-classical tradition) and models of endogenous growth that link HC to the rate of growth in the long run. Their conclusion is that 'from the methodological point of view the estimation of macroeconomic production functions including education as a regressor present a host of still unresolved issues. The most important of these is the measurement of human capital' (p. 195).

Empirical studies have demonstrated the existence of wide differences between the results of micro analyses (individual data) and those of macro ones. Micro studies find a substantially positive impact of educational attainment on earnings

(even if the variance in the coefficients is high); macro studies show very controversial results. There may be various reasons for this (Pritchett, 2001).

The first is the quality of the educational system, the very low quality of which has a null effect on abilities and skills. If this is the case, we should also find a null effect at a micro and individual level. Spence (1976) has proposed a model in which education does not raise productivity but is associated with higher earnings because it signals positive individual characteristics like ambition or innate abilities (according to Spence, it is likely that individuals with such characteristics invest more in education).

A second reason is the structure of the labour market and of the economic system. If there are no incentives (linked to economic openness or technological improvements) for demanding more skilled labour, a growth in the latter's supply may cause a reduction in correlative earnings. Schultz (1961), for example, showed that returns to education are almost null in the agricultural sector (where there is very low technological progress). Rosenzweig (1996) stressed the relation between returns to education and exogenous positive changes in technological conditions.

Finally, private and social returns may diverge. If skills acquired through education are applied to non-productive activities (e.g. to redistributive actions and lobbying), there may be a great difference between private (positive) and social (insignificant) returns. In many developing countries, the great majority of skilled people find jobs in the public sector because of political pressures (Gelb *et al.*, 1991). The link with productivity is consequently compromised.

In a recent survey of the link between education and growth, Hanushek and Wössmann (2007) claimed that 'educational quality, particularly in assessing policies related to developing countries, is THE key issue' (p. 1). Also Bosworth and Collins (2003) and Ciccone and Papaioannou (2005) have declared that considering quality is of decisive importance. Scholars are generally aware of the importance of quality (see, for example, Temple, 1999; Pritchett, 2001), but it is difficult to define an indicator for the quality of educational attainment (and hence for the level of HC).

Different approaches have been taken on the matter. Input indicators can be used as proxies of a school system's quality (investments in schools, percentage of expenditures on education over GDP: see Psacharopoulos, 1994). This approach has been criticized (Hanushek, 1996). It is possible to build specific indicators of quality in education (see Gundlach *et al.*, 2002, for a review), but data are not easy to obtain and inter-country comparability is low. According to Wössmann (2003), the results obtained through the use of such indicators are misleading because the construction methods of measures of educational quality are rather *ad hoc* (p. 265).

A third and more recent approach uses data on student performance in ability tests (in mathematics and science in particular) to proxy the quality of the system. Indicators of this kind are called 'cognitive skills indicators'. The spread of standardized surveys of this type (International Association for the Evaluation of Educational Achievement – IEA; Programme for International Student Assessment – PISA, etc.) has furnished similar data also for developing countries (where the problem of the quality of the educational system is even more important). However,

information on the school attended, its quality and test results are collected on samples of students, and it does not fit with other information on the individual or single household. Consequently, it is difficult to use in micro-approach research.

It should also be borne in mind that cognitive skills depend not only on the quality of the schooling system but also on other dimensions (family context, innate abilities, social context, i.e. dimensions of experience that impact on knowledge dynamics). For more details see Lee and Lee (1995), Barro and Lee (2001), Hanushek and Kimko (2000), Bosworth and Collins (2003) and Ciccone and Papaioannou (2005).

Externality problems also arise when measuring the quality of educational attainment. Learning does not depend solely on personal abilities; it is also influenced by those of the other students in the same class or school (peer effects: see Hanushek *et al.*, 2003). Robertson and Symons (2003), for example, conclude that after controlling for peer effects, quality indicators become insignificant.

Finally, educational advantages or disadvantages may perpetuate over generations (which is another form of externality). However, information on parents' wealth, educational attainment, qualifications and occupation is often unavailable.

5. Human Capital as a Latent Variable

HC in educational attainment – retrospective and prospective methods – has been measured as an aggregate indicator by means of numerous different variables (World Bank, 1995; United Nations, 2002; Wössmann, 2003). These variables – formative and reflective indicators – are related to different dimensions: educational attainment (schooling, training while working, experience, educational investment costs), non-cognitive skills, parental and family characteristics and earnings as a reflective indicator.

However, the OECD report (1998) defines HC as 'the knowledge, skill, competencies and attributes embodied in individuals that are relevant to economic activity' (p. 9). HC is a complex, multifaceted phenomenon with various intangible dimensions that are not directly observable and cannot be measured with precision by a single attribute, a set of attributes, or their combined sum on individuals or households.

Statistically speaking, HC is an LV. An LV has been defined in various ways in the literature. In a linear structural model, a variable is termed 'latent' if the equations cannot be manipulated so that they can be expressed as a function of manifest (observable) variables (Bentler, 1992). Therefore, an LV is seen as a latent cause of observed indicators and accounts for their variance in a measurement model (typically a factor model). Another common approach is to define an LV as 'an unobservable composite variable', by which is meant a latent effect resulting from a linear combination of observed indicators measured with errors.

On this basis, Dagum and Slottje (2000) have defined household HC at a microeconomic level as the multidimensional non-observable construct generated by personal ability, home and social environments, investments in the education of the household head and spouse whose effects are indirectly measurable by means

of the present value of a flow of earned income throughout an individual's life span.

The estimation method proposed by Dagum and Slottje (2000) overcomes the limitations of the prospective method developed by Farr. It starts by recognizing the true nature of HC as an LV and estimates it as a function of a set of quantitative and qualitative indicators. Retained from the information made available by a sample survey are the most relevant indicators for determining the HC of each economic unit. Having selected p quantitative and qualitative indicators (observed variables), $\boldsymbol{f}_1, \ldots, \boldsymbol{f}_j, \ldots, \boldsymbol{f}_p$, the HC is estimated as a linear combination of several observed indicators by the following linear equation:

$$z = l(\boldsymbol{f}_1, \ldots, \boldsymbol{f}_j, \ldots, \boldsymbol{f}_p) = l(\boldsymbol{F}) \tag{14}$$

where l is a unknown function, and z stands for the standardized (zero mean and unit variance) HC LV, specified by p standardized indicators connected with a person's characteristics and investment to acquire abilities made by the individual or his/her family ('formative indicators' in a structural equation modelling terminology; Tenenhaus *et al.*, 2005). To obtain solutions for equation (14), Dagum and Slottje (2000) choose the partial least squares (PLS) mode B (Wold, 1982) based on iterative univariate linear regressions of each $\boldsymbol{f}_j$ collected in $\boldsymbol{F}$ on a previous estimate of HC obtained as a linear combination of $\boldsymbol{F}$.

Before applying PLS, Dagum and Slottje (2000) quantify the categorical variables by means of principal components with mixed (nominal, ordinal, interval) data using the PRINCIPALS method pertaining to the optimal scaling ALSOS (Gifi, 1990).

Then z, the standardized distribution of the LV HC, is transformed into accounting monetary value by $\boldsymbol{h}^\circ = \exp(z)$. This transformation is obtained as the solution of the differential equation $\delta z = \delta \boldsymbol{h}^\circ / \boldsymbol{h}^\circ$, assuring that corresponding to absolute increments of the standardized variable z are relative increments of HC accounting monetary value $\boldsymbol{h}^\circ$.

Dagum and Slottje (2000) suggest that sample surveys give a highly representative flow of average earned incomes by age which can be used as input to the actuarial method of estimating the average HC embodied in an individual and the average HC of the population, in order to pass from a given household's quantity of HC to actual monetary values.

Consider the mean flow $h(x)$ of earned income expected in the cycle life for each specific household head of age x. The mean of $h(x)$ over ages, weighted by coefficients reflecting the age structure of the population, is the most representative candidate for the HC monetary mean of the entire population represented by the sample in the survey.

To estimate $h(x)$, the mean of earned income expected in the cycle life for a person (household head) of age x, the n households are grouped by age x of the household head and their corresponding earned incomes weighted by weighting factor yield $y(x)$, the average of earned incomes by age x. These averages, further smoothed by a seven term (3×5) moving average to remove large fluctuations, can be treated as representative cross-section data for the estimation of HC. Second,

under the assumption of the absence of temporal technological changes and without increase in HC productivity, the representative flow of average earnings of the economic units of age x, t years later, can be approximated by the average earnings $y(x+t)$ of the economic units of age $x+t$. Therefore, the HC monetary mean for household head of age x, $h(x)$, is equal to the actuarial value of the flow of average earned incomes $y(x+t)$, $t \geq 0$, actualized at the interest rate i and weighted by the probability $p(x, x+t)$ of surviving to age $x+t$:

$$\boldsymbol{h}(x) = \sum_{t=0}^{70-x} y(x+t)(1+i)^{-t} p(x, x+t) \tag{15}$$

Averaging $\boldsymbol{h}(x)$ over different ages x, weighted by $f(x)$, reflecting the age structure of the household head population, gives the HC monetary mean of the entire population:

$$\mu(\boldsymbol{h}) = \sum_{x=20}^{70} h(x) f(x) \Big/ \sum_{x=20}^{70} f(x) \tag{16}$$

where initial age and final age are considered fixed at 20 and 70 years respectively.

In real life, economic processes incorporate technological changes and higher educational levels. Hence the productivity of HC increases over time, inducing a process of economic growth. For these reasons, the cross-section average HC by age will not be equal to the lifecycle (time series) average HC. Assuming the annual rate r of productivity, maximal at 24 years and decreasing with age until 60 years, the counterparts of equations (15) and (16) are

$$\boldsymbol{h}^*(x) = \sum_{t=0}^{70-x} y(x+t)(1+i)^{-t}(1+r)^t p(x, x+t) \tag{17}$$

$$\mu(\boldsymbol{h^*}) = \sum_{x=20}^{70} h^*(x) f(x) \Big/ \sum_{x=20}^{70} f(x) \tag{18}$$

Equations (16) and (18) then represent the HC monetary mean of the entire population, assuming no productivity increase and productivity increase at an annual rate r respectively.

Assuming the last formulation as the most realistic and consistent with economic theory on HC, the HC distribution in monetary value $\mathbf{HC}^{\$}$ is obtained by transforming the HC distribution into accounting monetary values $\boldsymbol{h}^{\circ}$, utilizing the scaling factor $\tau = \mu(\boldsymbol{h}^*)/\mu(\boldsymbol{h}^{\circ})$ in order that $\mathbf{HC}^{\$}$ has mean $\mu(\boldsymbol{h}^*)$:

$$\mathbf{HC}^{\$} = t\boldsymbol{h}^{\circ} \tag{19}$$

where $\mu(\boldsymbol{h}^{\circ})$ is the mean value of the $\boldsymbol{h}^{\circ}$ distribution, weighting each observation by the number of households in the entire population that the ith sampled household represents in the sample.

Dagum and Slottje apply their method to estimate the 1983 USA HC while Földvári and van Leeuwen (2006) utilize the same method to estimate the 1995

Eastern Europe HC. Also Le (2006) estimates the 1995 monetary value of HC in New Zealand as a multidimensional LV by means of a PLS method (without using the above actuarial method) but he chooses mode A where each observed (reflective) indicator 'reflects' the LV HC.

6. A New Method for the Estimation of HC as a Latent Variable

The method proposed by Dagum and Slottje (2000) can be improved to obtain solutions more consistent with the HC economic theoretical framework (Dagum *et al*., 2007; Vittadini and Lovaglio 2007). In fact, since in this case the algorithm converges on a solution for the latent scores coincident with the first principal component of observed indicators (Wold, 1982), this approach only partially captures the economic definition of HC. In fact, HC is estimated by considering only its formative indicators $\boldsymbol{F}$ (corresponding to the HC retrospective definition) without embedding in the measurement model the earned income variable and thus the effects or returns of the investment in HC. On the other hand, in the Le (2006) proposal HC is estimated by considering only its reflective indicators (corresponding to the HC retrospective definition) without measuring the investment in acquiring skills and abilities by the individual or his/her family. To this end, for consistency with the definition by Dagum and Slottje (2000), HC must be simultaneously seen as an unknown function of formative indicators $\boldsymbol{F}$ and as a 'latent effect' underlying earned income (reflective indicator).

Formally, **HC** ($n \times 1$) on n economic units is assumed to be a unidimensional LV measured by a linear combination of (zero mean) formative indicators embedded in the full rank matrix $\boldsymbol{F}$ ($n \times p$):

$$\mathbf{HC} = \boldsymbol{F}\boldsymbol{g} + \boldsymbol{u} \tag{20}$$

where $\boldsymbol{g}$ denotes the ($p \times 1$) weight vector for the formative indicators and $\boldsymbol{u}$ ($n \times 1$) is the random component vector; simultaneously, **HC** is a 'latent cause' of the reflective indicator $\boldsymbol{y}$ which describes its effect (in this case HC, defined as an LV, is in bold).

$$\boldsymbol{y} = \mathbf{HC}\, k + \boldsymbol{\omega} \tag{21}$$

where k is the regression parameter of **HC** on $\boldsymbol{y}$ and $\boldsymbol{\omega}$ is the ($n \times 1$) vector of errors in the equation.

As in Dagum and Slottje (2000), for identification purposes we constrain the HC scores to zero mean and unit variance ($\boldsymbol{g}'\boldsymbol{F}'\boldsymbol{F}\boldsymbol{g} = 1$), and thus we render them as a standardized LV.

From this viewpoint, the household HC is estimated by the reduced form as the linear combination of household formative indicators $\boldsymbol{F}$ that has the best (in terms of goodness of fit) causal impact on the reflective indicator $\boldsymbol{y}$, the household earned income. Hence, by substituting equation (20) into equation (21), we obtain the reduced form:

$$\boldsymbol{y} = (\boldsymbol{F}\boldsymbol{g} + \boldsymbol{u})k + \boldsymbol{\omega} = \boldsymbol{F}\boldsymbol{v} + \boldsymbol{e} \tag{22}$$

where $\boldsymbol{v} = \boldsymbol{g}k$, $\boldsymbol{e} = \boldsymbol{u}k + \boldsymbol{\omega}$.

We initially estimate $\boldsymbol{v}$ by generalized least squares regression transforming $\boldsymbol{y}$ and $\boldsymbol{F}$ by means of matrix $\boldsymbol{\Omega}^{1/2}$, an $n \times n$ known matrix containing some form of correction for the non-sphericity (heteroskedasticity and/or autocorrelation) of errors. In sample surveys, a typical correction invokes weighted least squares, where $\boldsymbol{\Omega}$ is a diagonal matrix whose elements reflect how many units each sampled unit represents in the population. The estimated vector $\hat{\boldsymbol{v}}$

$$\hat{\boldsymbol{v}} = \boldsymbol{S}_F^{-1}\boldsymbol{F}'\boldsymbol{\Omega}\boldsymbol{y} \tag{23}$$

where $\boldsymbol{S}_F = (\boldsymbol{F}'\boldsymbol{\Omega}\boldsymbol{F})$ represents the effect of (transformed or weighted) formative indicators on (transformed or weighted) earned household income. Pre-multiplying equation (23) by $\boldsymbol{F}$ we obtain

$$\boldsymbol{F}\hat{\boldsymbol{v}} = \boldsymbol{F}\boldsymbol{g}k = \boldsymbol{F}\boldsymbol{S}_F^{-1}\boldsymbol{F}'\boldsymbol{\Omega}\boldsymbol{y} \tag{24}$$

and, since **HC** is a standardized variable, it follows that

$$\mathrm{Var}(\boldsymbol{F}\hat{\boldsymbol{v}}) = k^2\mathrm{Var}(\mathbf{HC}) = k^2 \tag{25}$$

Hence, the estimated parameter k which measures the effect of **HC** on earned household income $\boldsymbol{y}$ is given by

$$\hat{k} = \mathrm{Var}(\boldsymbol{F}\hat{\boldsymbol{v}})^{1/2} = \sqrt{(\boldsymbol{y}'\boldsymbol{P}_F\boldsymbol{y})} \tag{26}$$

where $\boldsymbol{P}_F = \boldsymbol{\Omega}\boldsymbol{F}(\boldsymbol{F}'\boldsymbol{\Omega}\boldsymbol{F})^{-1}\boldsymbol{F}'\boldsymbol{\Omega}'$ is the $n \times n$ projector on the space spanned by $\boldsymbol{F}\boldsymbol{\Omega}^{1/2}$.

Therefore, from (25) and (26), we obtain $\hat{\boldsymbol{g}}$, the effect of the formative indicators $\boldsymbol{F}\boldsymbol{\Omega}^{1/2}$ on **HC**:

$$\hat{\boldsymbol{g}} = \hat{k}^{-1}\hat{\boldsymbol{v}} = (\boldsymbol{y}'\boldsymbol{P}_F\boldsymbol{y})^{-1/2}\boldsymbol{S}_F^{-1}\boldsymbol{F}'\boldsymbol{\Omega}\boldsymbol{y} \tag{27}$$

These weights then provide the estimation of HC scores ($\hat{\boldsymbol{H}}_{\boldsymbol{C}} = \boldsymbol{F}\hat{\boldsymbol{g}}$), where $\hat{H}_C$ is estimated as the linear combination of the formative indicators $\boldsymbol{F}\boldsymbol{\Omega}^{1/2}$ that best fits earned household income $\boldsymbol{\Omega}^{1/2}\boldsymbol{y}$. In the case of many dependent indicators, this method can be generalized in a PLS path modelling framework by means of reduced rank regression models and redundancy analysis (Lovaglio, 2008). It should be noted that several indicators of **HC**, such as region, gender and marital status, are categorical, and hence that the formative indicators in $\boldsymbol{F}$ are of mixed type. Contrary to Dagum and Slottje (2000), who transform categorical indicators by maximization criteria of principal component analysis, we use the MORALS algorithm (Young *et al.*, 1976), within the ALSOS method, applying a multiple regression model with mixed data. Hence, we partition the matrix of transformed formative indicators $\boldsymbol{F}\boldsymbol{\Omega}^{1/2}$ (denoted here simply by $\boldsymbol{F}$) into two blocks of q quantitative and c categorical indicators, respectively. Equation (20) becomes

$$\mathbf{HC} = \boldsymbol{F}_{\mathrm{c}}\boldsymbol{g}_{\mathrm{c}} + \boldsymbol{F}_{\mathrm{q}}\boldsymbol{g}_{\mathrm{q}} + \boldsymbol{u} \tag{28}$$

where $\boldsymbol{F}_{\mathrm{c}}$ and $\boldsymbol{F}_{\mathrm{q}}$ are matrices composed of the column vectors of the corresponding variables, and $\boldsymbol{g}_{\mathrm{c}}$, $\boldsymbol{g}_{\mathrm{q}}$ are the corresponding parameters. The procedure simultaneously estimates the parameter vector $\boldsymbol{g} = (\boldsymbol{g}_{\mathrm{c}}, \boldsymbol{g}_{\mathrm{q}})$ and the categorical indicators $\boldsymbol{f}_{\mathrm{c}}$ (contained in $\boldsymbol{F}_{\mathrm{c}}$) by means of an iterative convergent algorithm

(Young *et al.*, 1976). Similarly to the case of only quantitative indicators, $\hat{\mathbf{HC}}$ is obtained by the linear combination of mixed formative indicators $\boldsymbol{F}$ that best fits $\boldsymbol{y}$. Finally, the actuarial method presented in Section 5 is applied to estimate the **HC** monetary value of the population. The above described method is utilized to estimate the US 2004 household HC (Dagum *et al.*, 2007) and to compare the 2000 HC stocks of workers in the USA and Italy in Lovaglio (2008); in a similar exercise, Oxley and Zhu (2002) and Le *et al.* (2006) use a prospective method to compare HC stocks of workers for New Zealand. An estimation of HC in a longitudinal perspective, based on administrative data for Lombardy (Italy), can be found in Lovaglio (2010).

7. Conclusions

The evidence on the shortcomings of classical methods to assess the value of HC stock grounded on national accounting schemes (both the retrospective approach based on the production cost of HC as a good measure of its value, and the prospective one based on the present value of labour income streams) has opened up new areas of research.

The multidimensional analysis of HC is now evident. HC is increasingly recognized as having several sources that are linked not only to formal education and training but also to culture, family background, social context and – to a significant extent – innate and non-cognitive abilities and skills. In recent contributions an attempt has been made to measure non-cognitive skills through LV methods (see, for example, Heckman *et al.*, 2005). At an aggregate level we may assume that the random distribution of these influencing factors permits the use of their average or stock to measure their contribution: we have specific surveys from which to collect data measuring schooling quantity and aggregate educational attainment, abilities and skills. However, as we have seen, we do not have robust methods with which to estimate the total quantity of HC in a population: the indicators are very poor and partial.

We now have a micro-founded model of choices by individuals, households or firms to invest in HC, and new data sets furnishing individual characteristics linked to HC. However, there are problems: a good estimation of the total costs of investing in HC is difficult to obtain; it is not easy to measure the quality of education, and it is difficult to use this dimension in an earning-function model (both at individual or aggregate level); the link between investments in HC and their returns depends on crucial assumptions such as a 'static' context and a strict linkage between earnings and productivity. Moreover returns may be 'hidden' in a firm's results and consequently not measured by earnings. Finally, we have problems of endogeneity and causality (a classic question in the literature is whether HC accumulation is the causal engine of economic growth or whether growth generates more HC – perhaps both processes operate), and several dimensions are unobservable (e.g. on-the-job learning, for which we use a very poor proxy like experience years; and likewise innate abilities and skills).

The definition of HC as a 'latent effect' of indicators regarding its investment and, at the same time, as a 'latent cause' of earned income (excluding that from wealth), measured on individuals or families, obtained by means of adequate structural equations models addresses all these problems. HC is now a 'non-observable variable' obtained through an *ad hoc* combination of a set of indicators concerning the result of the investment in education, in terms of working ability. The indicators reflecting these effects need not necessarily be expressed in monetary terms, and it is obvious that the operational definition is relevant because it links the object to be assessed with the objective conditions in which the phenomenon occurs (Biggeri, 2007) It becomes possible (Biggeri, 2007) 'to evaluate the possible contribution of an individual or a group of individuals to the economy of a community' and 'to measure the differential effect – in terms of labour and/or income – coming from the investment in education, for special segments of educational paths'. Biggeri also states that 'It is still an emerging research sector, but it is really very promising'.

In order to estimate HC as an LV, data sets where formative and reflective indicators are observed at a household and individual level as in the US Survey of Consumer Finances can be utilized. However, Oxley *et al.* (2008) affirm, with reason, that a possible drawback of LV methods is the lack of data on personal intelligence, ability and hard work because in this case, as previously stated, these essential characteristics cannot be taken into account in the HC estimation. In order to fill this gap new data sets that include formative indicators regarding individual education and work experience are needed.

Many improvements could be suggested for the LV HC model proposed in Section 6. Lovaglio (2008, 2010) takes into account in the HC latent model of the concomitant indicators, observed exogenous variables directly linked with the reflective indicators of an LV, without being embedded in its formative block (i.e. sex, ethnicity, marital status, area of residence, occupation, wealth of origin household, parents' socio-economical status, etc.). In fact, concomitant indicators reflect opportunity factors of HC formation, such as traditions, cultural elements, natural environmental factors, and some social, political, institutional elements may also have a causal impact on the LV scores. It can be opportune to introduce these kinds of indicators also as moderator indicators that interact with formative indicators, changing the direction and the strength of their relationship with the LV HC (Aguinis, 2004).

A single global model may not sufficiently describe situations characterized by heterogeneity. Local models could better individuate clusters of people, each of them characterized by the same relationship between the formative and reflective indicators and the HC LV (Frühwirth-Schnatter, 2006). Sensitivity analysis could be used to determine how 'sensitive' a latent HC model is to changes in the value of the parameters and in the structure of the model (Breierova and Choudari, 2001; Saltelli, 2009).

Suitable methods able to deal with missing data problems in LV models have to be proposed (Takahiro, 2005).

From the economic point of view, the insertion of the monetary estimation of household HC in a causal recursive HC model, such as Dagum's recursive

model (1994), allows researchers to explain the household HC, income and wealth determination and their distributions, and to derive the short- and long-term multiplier matrices, offering relevant information for the evaluation of policy choices on educational programmes, research and development, labour markets, regional development and more, e.g. concerning

1. quality of the educational and job training system, because household HC estimation gives a long-term indicator of the increase of technical, professional and scientific qualifications;
2. an increase in productivity connected with an accumulation of high levels of HC incorporated into economic processes;
3. a decrease in the inequality of the distribution of wealth and of capital income linked to the investment in HC.

Therefore, as Biggeri (2007) states 'It is still an emerging research sector, but it is really very promising' and as Silber (2007) puts it: 'This approach will become more and more popular in quantitative analyses of HC and more generally human development' and will be very useful for defining both more effective HC policies and their effects.

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